Encinitas-Solana Beach Coastal Storm Damage Reduction Feasibility Study

San Diego County, California

Attachment E1 – Economic Model

U.S. Army Corps of Engineers
Los Angeles District

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1 Study Area Overview

The study area lies in the coastal zone from the northern boundary of Batiquitos Lagoon to the terminus of Solana Beach. The two coastal communities primarily impacted by the project alternatives are Encinitas and Solana Beach, California. Beach fill will be placed within a subset of this study area from 0.5 miles north of the intersection of Daphne Street & Neptune Avenue southward to Sea Cliff County Park. This area will be referred to as Segment 1 and covers roughly one-third of the coast line of Encinitas. Beach fill will also be placed from the northern to southern boundary of Solana Beach. This area will be referred to as Segment 2.

2 Purpose & Concepts to Model

The purpose of this model is to quantify the benefits and costs of alternatives formulated to reduce coastal storm damages. Specifically the project alternatives have been formulated to reduce shoreline retreat. Shoreline retreat is defined as the gradual landward movement of the sea/land boundary as defined by the location of some tidal datum such as MSL. In the study area, this retreat is generally caused by shoreline erosion caused by wave attack of the beach and bluffs. Retreat of the coast may occur gradually, at a relatively uniform rate, or episodically, in large increments, followed by long periods of little or no retreat. Gradual retreat is well represented by annualized retreat rates; however, annualized rates do not adequately describe the nearly instantaneous retreat of several feet or tens of feet that may occur episodically. Episodic retreat affects both the seacliff face and bluff top. The seacliff is affected by large wave events eroding sea caves at the bluff toe and triggering block topping and block fall, collapsing these "notch caves". The sub aerial processes (rain, rilling, surficial overslope flow) acting on the bluff surface and crest generally produce a slower, more uniform erosion rate, but may also contribute to episodic failure over the longer term. In addition, deep-seated landslides can cut back into the coastal terrace upwards of 60 to 80 feet in a few hours or days. The figure below shows a typical bluff profile in the study area.

The project alternatives consist of varying amounts of initial beach fill followed by periodic beach renourishment for the duration of the study period. In addition one set of alternatives consists of a toe notch fill (see Notch in diagram above) in combination with initial and periodic beach fill. The reduction in coastal storm damages attributable to each project alternative is the with-project benefit and all associated construction, maintenance, mitigation, and monitoring expense is the with-project cost.

The observed, historical behavior of bluff-top parcel owners informed the modeling for the without project coastal storm damages and hence the model quantifies this concept. When episodic retreat and failure of the bluff tops occurs, termed an "episodic event", land is lost and coastal structures are threatened. In response many but not all bluff-top property owners seek permission to construct seawalls to protect their property from further erosion and collapse. Others will not or cannot construct a seawall before an episodic event renders their structure unsafe for occupancy. These two distinct responses to the process of storm surge, toe notch erosion, and bluff-top collapse form the basis of the economic modeling done in this study.

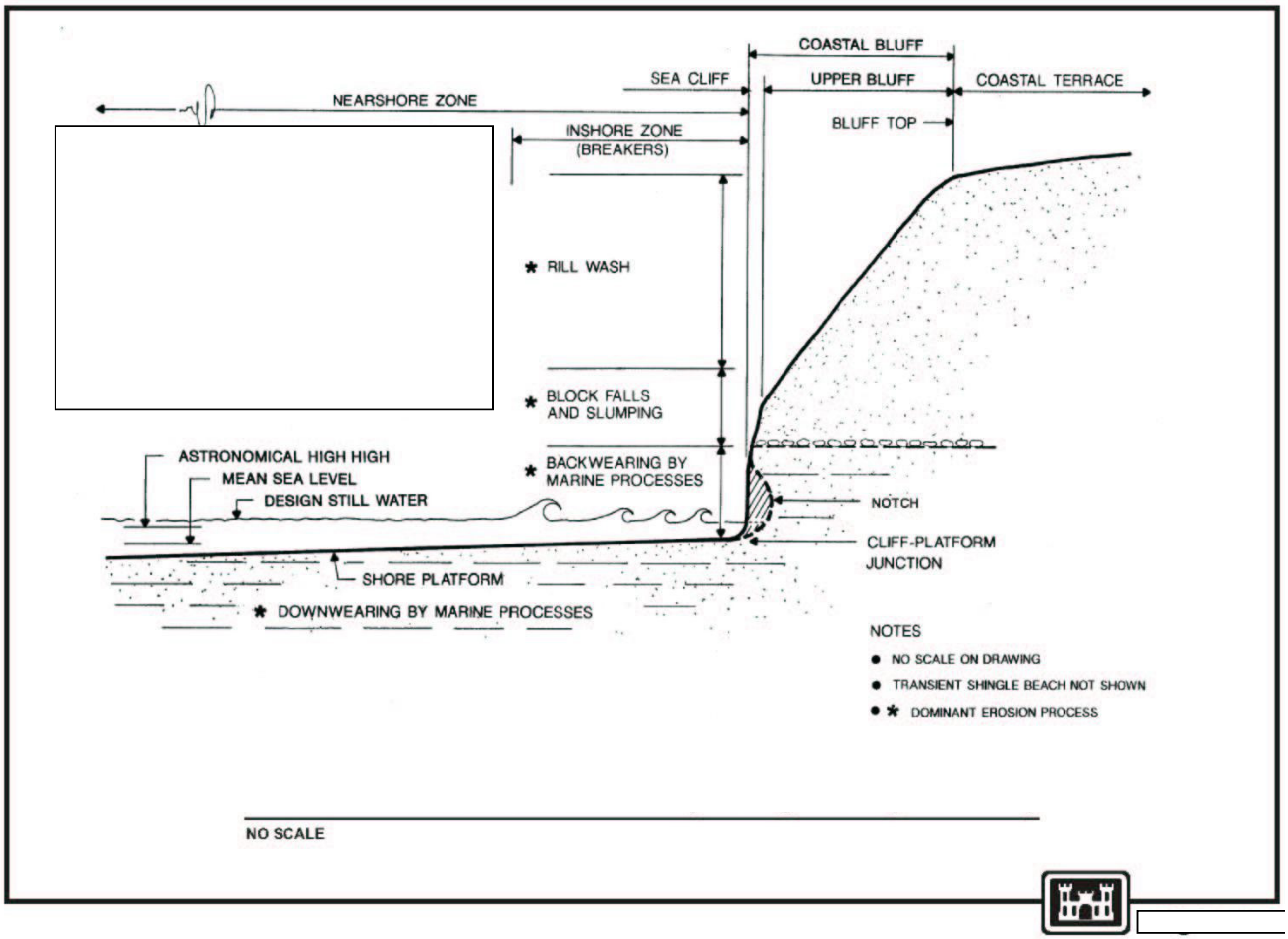


Figure 2.1-1 Typical Coastal Bluff Profile (Looking North up the Coast)

Recreation benefits of each project alternative also have been evaluated. Beach visitors can be impacted by long-term shoreline erosion, seasonal variations in the shoreline, and sea-level rise because these phenomena alter the area available for beach recreation. Visitations to these beaches steadily decline as the area that can be used to recreate gets smaller and can accommodate fewer visitors. Eventually this unmet demand results in potential visitors choosing to transfer to beaches outside the study area. The process of storm surge, sea-level rise, and beach erosion forms the basis for recreation modeling done in this study using the USACE Unit Day Value method.

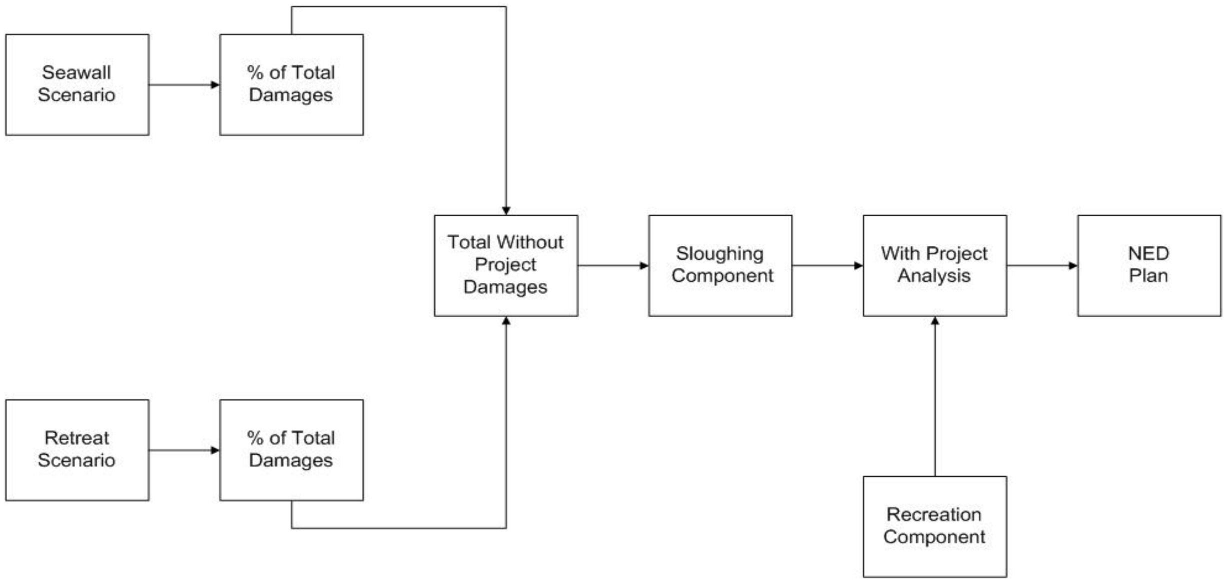


Figure 2.1-2 Flowchart of Coastal Damage Model

2.1 With-out Project Components

Under with-out project conditions the model is designed to capture the economic values associated with the behavior of property owners and beach visitors in the communities of Solana Beach and Encinitas in response to impending bluff-top collapse, loss of beach area for public recreation, and wave force damages to a major highway and nearby structures. Each of these concepts has a distinct component within the model. The components are:

Coastal Damages

- Armoring Scenario
- Retreat Scenario
- Wave Force Damage Analysis

Recreation Values

- Recreation Analysis Without Project

Under the *Armoring Scenario* all bluff-top property owners are 'proactive'—they can and do protect their property with seawalls before structure loss occurs. It has been designed to capture the damages from land and staircase loss after episodic events, and seawall construction and maintenance after the "triggering event". The triggering event is the bluff top setback distance when a homeowner decides to apply for permitting to construct a seawall. This triggering event is a probability distribution based on historical setback distances at the time an approved seawall application was submitted to the California Coastal Commission (CCC). All data was provided by the CCC and only included approved seawall permits within the study area and within the past decade. Seawalls analyzed in this study are approximately 35 feet tall and only designed to protect the lower portion of the bluff rather than the entire bluff face, which can be 100 feet or taller. Weathering at the bluff top edge, termed sloughing, can occur after a seawall has been constructed on the lower portion of the bluff and this phenomenon is addressed in the Sloughing Damages Analysis.[1]

Retreat Scenario captures the damages from land, structure, structure contents, and staircase loss after episodic events. Under this scenario all bluff-top property owners are 'passive'—they do not act early enough to protect their property and many vulnerable structures are rendered uninhabitable by repeated episodic events. Demolition costs are applied to these uninhabitable structures and the remaining parcel areas are considered lost. Even some interior (2nd row) parcels and city infrastructure could be damaged by episodic events without intervention. Since outside intervention is likely before city infrastructure is irreparably damaged, seawalls are assumed to be constructed before the second row of parcels can be damaged by episodic events.

Wave Force Analysis captures wave force damages in the low-lying area of Reach 7. This can cause partial or full closure of a stretch of Pacific Coast Highway connecting Encinitas and Solana Beach and flooding to nearby structures and contents. Travel delays and damage to structures and contents inside these structures can occur. [2]

Recreation Analysis captures the recreation values from the study area beaches under with and without-project conditions. Recreation values adjust with changes to the future shoreline (usable beach area). Beach visitors to the study area routinely recreate on the wet beach, which is above MSL but below the dry beach berm, where dry beach is not available. Both with and without project recreation values are calculated separately for wet and dry beach areas based on this observed pattern.

[1] See *With Project* section.
[2] Could not justify project for Reach 7 based on economic considerations because of limited without project damages.

Table 2.1-1 TABLE OF WITH-OUT PROJECT MODELING COMPONENTS

Modeling Component	Concept	Process
Armoring Scenario	Owners respond to toe notch erosion before episodic events damage structures; seawalls built and first row of structures preserved	1. Episodic event 2. Reduced set back distance from bluff 3. Seawall construction triggered and structure preserved
Retreat Scenario	Owners do not or cannot respond to toe notch erosion before episodic event damages structure; first row of structures lost, second row preserved by seawall	1. Episodic event 2. Reduced set back distance from bluff 3. Further episodic events 4. Structure collapse
Wave Force Damage Analysis[3]	Storm-induced flooding in low-lying area causes road closures and damage to structure contents (reach 7 only)	1. Storm-induced overtopping 2. Partial/full road closure & flooding of structures 3. Travel delays & structure content damages
Recreation Analysis	Sea-level rise, long-term erosion and beach renourishments change the shoreline (beach area); beach area impacts recreation experience and carrying capacity	1. Storm surge & sea-level rise (without project) 2. Reduced beach area 3. Reduced recreation value -- OR – 1. Beach Renourishment (with project) 2. Increased/maintained beach area 3. Increased/maintained recreation value

2.2 With Project Components

Valuing each project alternative involves capturing the reduced coastal storm damage to bluff-top property owners, increased recreational opportunities to beach visitors, and residual bluff-top erosion. Each of these concepts has a distinct component within the model. The components are:

Reduction in Coastal Damages

BC Analysis
Reduction in Armoring & Retreat Scenario Damages
Reduction in Wave Force Damages[4]

Recreation Values

Recreation Analysis With Project

Residual With Project Damages

Sloughing (Residual) Damages

BC Analysis calculates the net benefits of each project alternative. It weights without project damages established in *Armoring Scenario* and *Retreat Scenario* by estimated likelihood of occurrence to derive the expected without project damages, then applies the partial benefit capture curve to derive the reduction in coastal storm damages that correspond with each project alternative. Weighting for the mutually exclusive Armoring and Retreat Scenarios is

[3] Could not justify project for Reach 7 based on economic considerations because of limited without project damages
[4] Ibid.

derived from the intensity and frequency of bluff-top erosion events during the study period as well as historical parcel owner behavior.[5] Last the costs of each project alternative are calculated and the project alternative benefits and costs are presented along with net benefits and BC ratios.

The BC Analysis spreadsheet evaluates the costs and benefits of project alternatives that reduce coastal storm damages and wave force damages. These have been termed *Reduction in Armoring & Retreat Scenario Damages* and *Reduction in Wave Force Damages*.

Reduction in Armoring & Retreat Scenario Damages is the partial reduction in coastal storm damages each project alternative offers and is derived from *Armoring & Retreat Scenario*. First *Retreat Scenario* and *Armoring Scenario* damages are weighted by the expected probability of occurrence and combined to derive the weighted damages. Next *Sloughing (Residual) Damages* is subtracted from the weighted damages to derive the maximum preventable damages. Finally each project alternative is evaluated for its level of coastal storm damage protection using the Partial Benefits Capture Curve. The resulting "partial coastal storm damage reduction benefits" are derived and presented in *B-C Analysis*, BENEFITS SEG1/2 sheets.

Reduction in Wave Force Damages captures the reduction in wave force damages that would have occurred in the absence of a project alternative in the low-lying area of Reach 7. [Due to the limited number of affected structures and limited travel delays there is no project alternative that is economically viable and consequently the with-project analysis was not performed.]

Recreation Analysis with Project captures the recreation values from the study area beaches under with project conditions. Recreation values adjust with changes to the usable beach area and increased demand for beach visitations. The difference between with and without project recreation values are the recreation benefits used in the calculation of the each project alternative's benefits in *BC Analysis*.

Sloughing Damage Analysis evaluates the damages from weathering of the upper bluff and these damages are subtracted from the without project damages since the proposed project will not avoid these damages in the future.

2.3 Weighting Armoring & Retreat Scenarios[6]

In order to derive the expected without project damages, Armoring Scenario and Retreat Scenario were weighted. The Retreat Scenario weighting relies on a combination of objectivity and subjectivity to establish the probability that parcel owners do not or cannot act in time to episodic events from collapsing their structures. One minus this probability is the Armoring Scenario weighting. To derive the objective portion of the weighting, we recorded the relative number of episodic events that occurred in such a pattern that we would not expect even proactive, determined owners to be able to respond by building a seawall before their structures collapsed. This objective consideration provides the minimum possible weighting for *Retreat Scenario*. After establishing this minimum weighting, it was adjusted upward based on subjective considerations for owners that do not have the financial means or timely construction permits to build seawalls in time as well as those that do not construct seawalls in time for other personal reasons.

[5] Refer to *Weighting Armoring & Retreat Damages* section for further details.
[6] How the weighting was determined is detailed in the *With Project Conditions* section under the heading *Weighting Armoring & Retreat Scenarios*.

Table 2.3-1 COMPARISON OF WITH & WITHOUT PROJECT MODEL COMPONENTS

Without Project Component	With Project Component	With-Project Concept
Armoring Scenario	***Reduction in* Armoring Scenario Damages**	Each project alternative's partial reduction in coastal damages assuming all affected parcel owners build seawalls prior to structure failure under without project conditions; analysis done in BC Analysis spreadsheet.
Retreat Scenario	***Reduction in* Retreat Scenario Damages**	Each project alternative's partial reduction in coastal damages assuming no affected owners build seawalls prior to structure failure under w/o project conditions; analysis done in BC Analysis spreadsheet.
Wave Force Damage Analysis	***Reduction in* Wave Force Damages**	The maximum possible reduction in wave force damages in low-lying areas (reach 7)
Recreation Analysis without Project	**Recreation Analysis with Project**	Establish with project recreation values; difference in with and without project values are recreation benefits from each project alternative
N/A[7]	Sloughing Damage Analysis	Residual long-term erosion to the bluff top continuing to occur with project alternative implemented; subtracted from storm-damage benefits of *Armoring and Retreat Scenario*
N/A	BC Analysis	Apply maximum reduction in coastal damages (after accounting for residual sloughing damages) to "Partial Benefit Capture Curve" to derive actual/realized reduction in coastal damages (with project benefits) for each combination of fill alternative and renourishment cycle; calculate fill costs of each combination; determine net benefits

[7] Some sloughing damages would occur under without project conditions once property owners construct seawalls (Armoring Scenario). However factoring in this residual erosion would have minimal impact to the analysis.

2.4 <u>Sea-Level Rise</u>

Two scenarios for sea-level rise were included in the model: low and high. Based on the USACE guidance[8] the historic rate of sea level change should be used as the "low" rate. The "high" rate of local sea level change should be estimated using the modified Curve III from the 1987 NRC report.

Each model component is affected by sea-level rise. In *Armoring & Retreat Scenario* sea-level rise affects the frequency and intensity of episodic events, which changes the rate of property loss and seawall construction. In *Wave Force Damage Analysis* sea-level rise affects the frequency of flooding to structure contents and frequency and duration of road closures. In *Recreation Analysis* sea-level rise impacts the area available for recreation and produces lower recreation values under high-sea level rise compared to low. *Sloughing Damage Analysis*, which is erosion from weathering at the upper bluff, is not impacted by sea-level rise.

3 Without Project Conditions

SPREADSHEET

*Armoring Scenario**	*Erosion Rates*
*Retreat Scenario**	*Erosion Rates*
Wave Force Damage Analysis	
Recreation Analysis Without Project	*Recreation Analysis Without Project & With RSBP II Alt 1/2*
RSBP II Analysis	

*Excel Add-in @RISK must be running

The without-project damages are generated from land loss due to bluff-top collapse, beach erosion due to storm surge and sea-level rise, and flooding due to storm surge. The model assesses land loss and associated damages under two different scenarios: *Retreat Scenario* and *Armoring (Seawall) Scenario*. Each scenario models two possible outcomes depending on how each parcel owner and the regulatory agencies with jurisdiction over seawall construction behave. For financial, personal, regulatory, or other reasons some owners will not build seawalls before their structures are rendered uninhabitable from bluff-top collapses. This behavior is captured under the *Retreat Scenario*, where all owners do not build seawalls in time to protect their structures. On the other hand many owners will be able to build seawalls before their structures are rendered uninhabitable. In fact, approximately 39% of the study area parcels are already protected to some extent by seawalls. This behavior is captured in the *Armoring Scenario*, where all owners do build seawalls in time. Historically bluff-top structures threatened by imminent bluff-top collapse have been able to obtain permits and construct seawalls in time so more weight is given to the *Armoring Scenario* than the *Retreat Scenario*.

[8] EC 1165-2-209 and white paper *Approach to Incorporate Projected Future Sea Level Change into the Encinitas & Solana Beach Shoreline Protection Feasibility Study* and CEQA and NEPA Compliance Efforts.

Retreat Scenario assesses land loss from bluff-top collapse and any associated structure damages, stairway loss, seawall construction to preserve all infrastructure and land interior to the first row of bluff-top parcels but the first row of structures are not protected in time and are rendered uninhabitable The *Armoring Scenario* component also assesses land loss from bluff-top collapse but seawall construction is initiated prior to structure damage to the first row of bluff-top parcels rather than after structure damage.
Recreation Analysis assesses the recreation values generated by the beaches as they erode and become inundated due to long-term erosion and sea-level rise. The Travel Delay & Flooding component assesses travel delays costs due to the road closures and content damages inside flooded structures.

3.1 Armoring Scenario

SPREADSHEET[9]

Armoring Scenario *Erosion Rates*

3.1.1 Layout & Process

The *Armoring* (Seawall) *Scenario* assesses land loss from bluff-top collapse and any associated stairway loss and seawall construction to preserve the first row of structures on the bluff-top parcels. This component of the model applies a random erosion event to the initial bluff-top setback distance that is dependent on each parcel's initial toe notch depth and location within the study area. After the episodic event is applied a new setback distance is determined--land and staircase losses are calculated if applicable. The seawall trigger is applied to this new setback. If the seawall trigger is equal to or less than the setback distance, a permit is sought to construct a seawall and a delay of one to three years is applied before it can be constructed. When a seawall is constructed the cost of that seawall construction is applied and each subsequent year maintenance costs are assessed. No further damages from episodic events occur. If no seawall is constructed then another random erosion event occurs and the seawall trigger is applied to this new setback distance. This process is laid out in the diagram below.

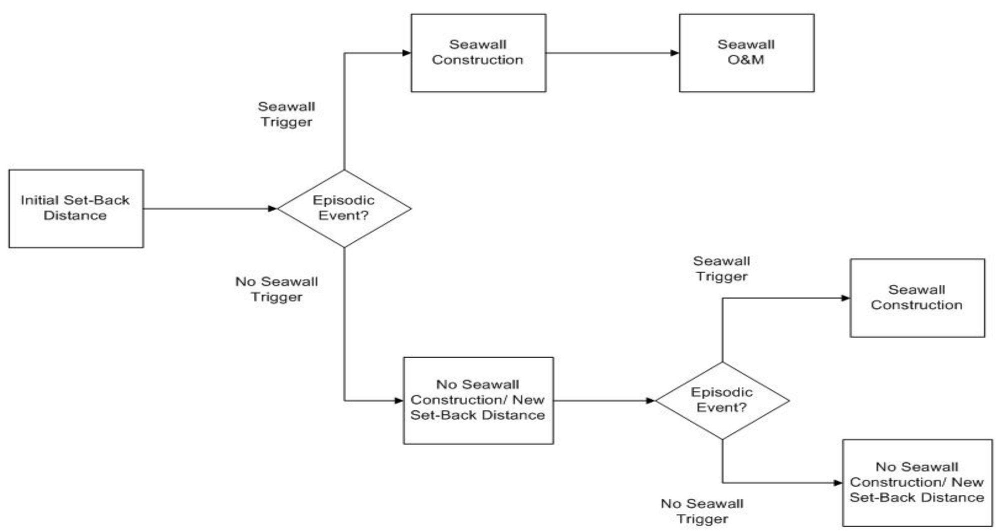


Figure 3.1-1 Seawall Armoring Component

[9] A table describes the layout and function of each sheet in the Armoring Scenario spreadsheet at the end of this section. Note Excel Add-in @Risk must be running when the spreadsheet is open.

3.1.2 Episodic events

Armoring Scenario draws erosion data from a simulation of episodic events in the separate Erosion Rates spreadsheet. The Erosion Rates spreadsheet consists of 50 years of episodic events separated by location (study area reach) and initial toe notch depth (0, 2, 4&6 feet). Each combination of location and toe notch depth has 1,000 simulated episodic events for each year of the study period. Each of these 1,000 rows has an equal probability of being drawn by the uniform probability function located in the VAR sheet within *Armoring Scenario*. Once drawn the episodic event (erosion rate) is applied to the Annual Erosion Rates sheet within *Armoring Scenario*. These episodic events form the basis for all damages. Loss of Staircase sheet calculates losses when staircases are damaged by episodic events. The Land Loss sheet calculates losses when land is damaged by episodic events. Armoring Construction and Armoring O&M sheets calculate costs after seawalls are constructed and subsequently maintained.

<u>Armoring Scenario: seawall Application, Delay, & Construction</u>

Historical seawall permit data in the study area was used to establish a probability distribution of bluff-top to structure setback distances immediately preceding application for a seawall permit, which must be done before a seawall can be legally constructed.[10] The triggering event ('seawall trigger') specified by the probability distribution =RiskExtvalueAlt(0.05,4,0.95,36,RiskTruncate(-5,40)) located in VAR sheet within *Armoring Scenario* establishes the setback distances from structure to bluff-top edge that causes the parcel owner to seek a seawall construction permit. Under the armoring scenario we have assumed that all parcel owners respond to the 'seawall trigger' by applying for a permit and all seawall permit applications are approved, although not in that same year. The model follows historical precedent: episodic events eventually threaten the structure; the affected parcel owner seeks a seawall permit; successful permit applications are typically approved in 1-3 years; and a seawall is constructed shortly thereafter. To model the delay we have added a seawall construction delay of one, two, or three years after the seawall permit application has been submitted (i.e. the 'seawall trigger delay'). The 'seawall trigger delay' distribution is located in *Armoring Scenario* VAR sheet and is added to the year a seawall permit is applied for. In this way the Armored Permit sheet keeps track of if and when a parcel owner seeks a permit using the 'seawall trigger' and the 'seawall trigger delay' of 1-3 years is added to determine when the permit will be approved and the seawall can be constructed, which occurs in the Armored Parcel sheet. Seawall operation and maintenance costs follow the year after seawall construction until the end of the study period. Parcels with seawalls or properties labeled "exclude" in the Parcel Database do not incur damages.

<u>Additional Damages: Staircases</u>

Some parcels in the study area have staircases leading from the bluff top to the beach. Over time episodic events have caused several of these staircases to become unsafe or even collapse. Under without project conditions we expect more staircases to be lost. The replacement cost for a private staircase has been estimated at $42,000. Typically, after three feet of bluff-top erosion a staircase can fail. Therefore the "staircase trigger" occurs in the year there is three or more feet of cumulative erosion to the bluff top—in that year the staircase is

[10] Historic seawall construction data from the study area was provided by the California Coastal Commission. For further details see *Armoring Scenario* in the introduction.

lost. Since the number of staircases within Segment 1 & 2 is limited, the impact to without project damages is minimal. To see the 'staircase trigger' and how staircase damages are calculated refer to *Armoring Scenario* spreadsheet and VAR and Loss of Staircase sheets.

Table 3.1-1 ARMORING SCENARIO BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet	Purpose/Description	Inputs	Outputs
VAR	Present key assumptions/inputs in one sheet	Staircase loss value, seawall construction & maintenance costs, land loss value, distribution of setback distances for seawall construction trigger, seawall trigger delay	n/a
Parcel Database	List all bluff-top parcels in Encinitas and Solana Beach with setback distance, parcel & structure area, structure value, toe depth	Area MFR&condos o condo & duplex area M&S o construction quality & condition valuations from Marshall & Swift	Structure depreciated replacement values
Area MFR&condos	Area of condos and duplexes by housing unit	n/a	n/a
M&S	Structure value per square foot by housing type, construction quality, and condition	Marshall & Swift Valuation Guide	n/a
Armored Permit	Determine if and when seawall permit application is submitted	VAR o seawall trigger delay Parcel Database o parcel type (land, structure, exclude), protected by seawall Parcel Erosion o current year setback distance after bluff-top collapse	Year when seawall application is submitted (year change from NO to YES occurs) present on parcel
Armored Parcel	Determine if and when seawall is constructed, which occurs 1-3 years after applying for seawall permit (see Armored Permit sheet). This delay is called the 'seawall trigger delay' and is a uniform probability distribution located in VAR sheet	VAR o seawall trigger Parcel Database o parcel type (land, structure, exclude), protected by seawall Parcel Erosion o current year setback distance after bluff-top collapse	Years when seawall is present on parcel (from year of seawall construction to end of period of analysis)
Year of Armoring	Determines year of seawall construction	Armored Parcel	Year seawall is constructed on parcel
Armored Constr.	Cost to construct seawall and year construction occurs	Armored Parcel o year of seawall construction VAR, Parcel Database o length of parcel/seawall and fixed & variable costs of seawall construction	Seawall construction costs
Armoring O&M	Annualized repair costs of seawall commencing the year following construction	Parcel Database, Armored Parcel o period seawall is present, length of parcel/seawall VAR o fixed & variable costs of seawall repair	Seawall repair costs (annualized)

Sheet	Purpose/Description	Inputs	Outputs
Land Loss	Land value lost to bluff-top collapse	Armored Parcel, Parcel Database ○ determine parcels to exclude and include Annual Erosion Rates, Parcel Database, VAR, Armored Parcel ○ determine area and value per sq foot of land loss to derive value of land lost	Value of bluff-top land lost to bluff-top collapse
Loss of Staircase	Staircase value lost to bluff-top collapse	Parcel Database ○ exclude parcels with seawalls and parcels coded "Exclude", include parcels with staircases Annual Erosion Rates ○ cumulative bluff-top land loss VAR ○ cumulative land loss before staircase is lost	Value of staircase lost to bluff-top erosion
Total Damages	Sum the damages from lost land, lost staircases, and seawall construction and maintenance	Armored Constr. Armoring O&M Land Loss Loss of Staircase	Sum of the values from *Armored Costr., Armoring O&M, Land Loss,* and *Loss of Staircase*
PV Losses	Calculate the present value of the damages	Armored Constr. Armoring O&M Land Loss Loss of Staircase	Present value of *Armored Costr., Armoring O&M, Land Loss,* and *Loss of Staircase* by reach
Summary of Losses	Summary presentation of total damages by reach from *PV Losses*	PV Losses	Present Value of total damages by reach
Annual Erosion Rates	Simulate bluff-top land loss based on initial toe notch depth	Erosion Rates (separate spreadsheet) ○ distribution of land erosion events dependent on toe notch depth Parcel Database ○ initial toe notch depth by parcel	Bluff-top land loss in linear feet
Parcel Erosion	Derive structure setback distance from bluff-top during current year	Parcel Database ○ initial structure setback distance from bluff-top Annual Erosion Rates ○ bluff-top land loss in linear feet	Structure setback distance from bluff-top during current year
Erosion Rates (separate spreadsheet)	Probably distribution of simulated bluff-top erosion events dependent on initial toe notch depth and location within study area	n/a	Annual Erosion Rates sheet, bluff-top erosion for current year

3.2 Retreat Scenario

SPREADSHEET[11]

Retreat Scenario[12] *Erosion Rates*

3.2.1 Layout & Process

Retreat Scenario assesses land loss from bluff-top collapse and any associated stairway loss, structure loss, structure demolition costs and seawall construction to protect structures and infrastructure beyond the first row of bluff-top parcels. This component of the model applies a random episodic event (bluff-top erosion) to the initial bluff-top setback distance that is dependent on initial toe notch depth and location within the study area. This determines the new setback distance and any land and staircase losses. After the episodic event is applied a new setback distance is determined--land and staircase losses are calculated if applicable. If a structure is lost then structure demolition costs are applied. If erosion leaves less than 15% of the original parcel in place, then a seawall is constructed to ensure interior infrastructure is protected. Each subsequent year after a seawall is constructed seawall maintenance costs are applied. No further damages from episodic events occur to land, structures, and infrastructure interior to the first row of bluff-top parcels. This process is laid out in the diagram below.

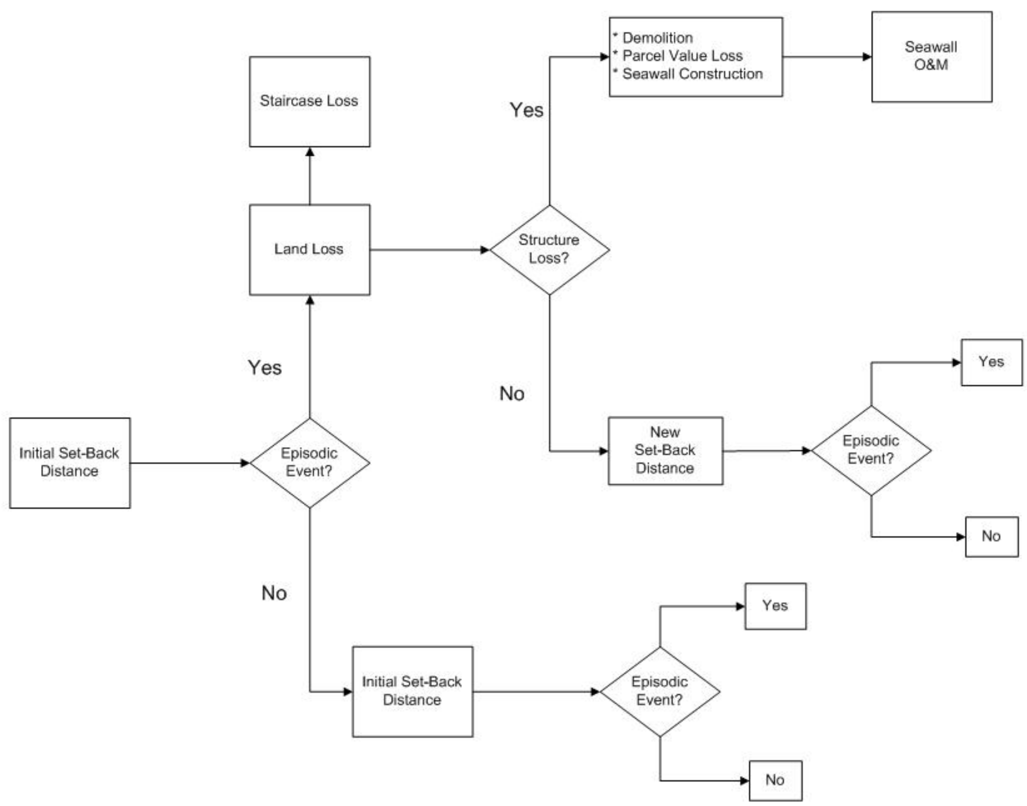


Figure 3.2-1 Retreat Component

[11] A table describes the layout and function of the Retreat Scenario spreadsheet at the end of this section.
[12] Excel Add-in @RISK must be running

3.2.2 Episodic events

Retreat Scenario draws erosion data from a simulation of episodic events in the separate Erosion Rates spreadsheet. The Erosion Rates spreadsheet consists of 50 years of episodic events separated by location (study area reach) and initial toe notch depth (0, 2, 4 & 6 feet). Each combination of location and initial toe notch depth has 1,000 simulated episodic events for each year of the study period. Each of these 1,000 rows has an equal probability of being drawn by the uniform probability function located in the VAR sheet within *Retreat Scenario*. Once drawn the episodic event (erosion rate) is applied to the Annual Erosion Rates sheet within *Retreat Scenario*. As in *Armoring Scenario* these episodic events form the basis for all damages. Loss of Staircase sheet calculates losses when staircases are damaged by episodic events. The Land Loss sheet calculates losses when land is damaged by episodic events. Armoring Construction and Armoring O&M sheets calculate costs when seawalls are constructed and subsequently maintained.

3.2.3 Seawall Trigger

Unlike *Armoring Scenario* the seawall trigger has been modified to occur after the structure has been rendered uninhabitable by episodic events and once only 15% of the original parcel area remains. If the parcel does not have a structure, a seawall is constructed once 15% of the original parcel area remains. Under the *Retreat Scenario* a seawall is constructed after the first row of parcels are lost because further erosion would undermine major public infrastructure such as roads, sewer lines, and power lines without this intervention. We have presumed that resources would be made available to construct seawalls and prevent this catastrophic scenario.

3.2.4 Additional Damages

Retreat Scenario and *Armoring Scenario* are laid out similarly (see table below). However since the first row of structures are lost under *Retreat Scenario*, their value along with content damages and demolition costs have been added to *Retreat Scenario* under Demolition and Structure Damages sheets. The Structure Damages sheet calculates losses at the depreciated structure value and a portion of the content value. Since structures subject to episodic erosion events generally become structurally unsound and uninhabitable rather than immediately falling off the cliff, only a randomly assigned percentage from 10% to 50% of the content value is considered lost. The total content value is a percentage of the depreciated structure value that varies by usage type (SFR and MFR).[13] The other sheets unique to the *Retreat Scenario* are Land Loss Bluff, Land Loss Non Bluff, Return Land Value, Structure Loss, Year of Structure Loss, Structure Damages, and Parcel Erosion.

- *Land Loss Bluff* calculates the value of bluff top land lost to episodic events with bluff top land defined as any land lost in periods prior to structure failure. In the year when the structure is lost any remaining land in the parcel is also considered lost and valued as non-bluff top.
-
- *Land Loss Non Bluff* calculates the value of non bluff top land lost to episodic events with non bluff top land defined as all land lost in the period of structure failure plus any remaining land on the parcel. When a structure is not present on the parcel, all land lost is valued as non bluff top.

[13] Refer to the Parcel Database sheet for content and structure value calculations.

- *Return Land Value* calculates the bluff-top premium (bluff top price minus non bluff-top price) for all bluff-top land lost up to the year of structure loss. This amount is subtracted out in the Total Land Loss sheet to reflect the transfer of bluff top premium to the adjacent interior parcel in the year the first-row structure is lost.

- *Structure Loss* calculates if and when a structure is lost due to episodic erosion events. This is indicated by the switching from "No" to "Yes" to indicate that a structure has failed and remains in that state for the remainder of the study period.

- *Year of Struct Loss* indicates only the year the structure failure occurs by switching from 0 to 1. This is pulled from the Structure Loss sheet

- *Structure Damages* uses the year the structure fails from the Year of Struct Loss sheet to assign structure damages and content damages in that year. The depreciated structure value and portion of contents that are damaged is calculated in the Parcel Database sheet.

- *Parcel Erosion* is similar to *Setback Erosion* because both apply the annual erosion rates to analyze cumulative erosion. The difference is that *Parcel Erosion* applies cumulative erosion to the length of the parcel to determine the remaining parcel length whereas *Setback Erosion* only applies erosion rates to the structure setback distance to determine the remaining setback distance.

If the parcel does not have a structure, all land loss occurs at the non bluff top value. Parcels with seawalls prior to the study period or properties labeled "exclude" in the Parcel Database sheet do not incur damages.

Table 3.2-1 RETREAT SCENARIO BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet	Purpose/Description	Inputs	Outputs
VAR	Present key assumptions/inputs in one sheet	Staircase loss value, seawall construction and structure demolition costs, and land loss value	n/a
Parcel Database	List all bluff-top parcels in Encinitas and Solana Beach with setback distance, parcel & structure area, structure value, content value, and toe depth	Area MFR&condos ○ condo & duplex area M&S ○ construction quality & condition valuations from Marshall & Swift	Structure depreciated replacement values and content loss values applied if and when the structure fails
Area MFR&condos	Area of condos and duplexes by housing unit	n/a	n/a
M&S	Structure value per square foot by housing type, construction quality, and condition	Marshall & Swift Valuation Guide	n/a
Structure Loss*	Determine if and when structures are lost during period of analysis	VAR ○ Setback length causing structure failure Parcel Database ○ parcel type (land, structure, exclude), protected by seawall Setback Erosion ○ remaining setback length by year	Years when structure is lost and seawall is present on parcel (from year of structure loss to end of period of analysis)
Year of Struct* Loss	Determines year of structure failure/loss	Structure Loss	Year structure is lost

Sheet	Purpose/Description	Inputs	Outputs
Parcel Loss* (Armoring)	Determine if and when parcels are considered lost, which is the year of seawall construction. Parcel is considered lost when 15% or less of the original parcel remains.	VAR ○ Parcel length causing parcel loss and seawall construction (“Armoring trigger") Parcel Database ○ parcel type (land, structure, exclude), protected by seawall, seawall construction ‘trigger’ Parcel Erosion ○ remaining parcel length by year	Years when parcel is considered lost and seawall is present
Year of Parcel Loss*	Determine year parcel is considered lost, which is year of seawall construction (armoring).	Parcel Loss (Armoring)	Year parcel is considered lost and seawall constructed on parcel
Armored Constr.	Cost to construct seawall and year construction occurs	Year of Struct Failure ○ year of structure failure and seawall construction VAR, Parcel Database ○ length of parcel/seawall and fixed & variable costs of seawall construction	Seawall construction costs
Armoring O&M	Annualized repair costs of seawall commencing the year following construction	Parcel Database, Struct Failure or Parcel Loss ○ period seawall is present, length of parcel/seawall VAR ○ fixed & variable costs of seawall repair	Seawall repair costs (annualized)
Demolition*	Structure Demolition costs	Year of Struct Failure, Parcel Database ○ year of structure failure, area of structure VAR ○ demolition costs per sq foot	Structure demolition costs
Structure Damages*	Value of Structures lost	Year of Struct Failure ○ year structure failure occurs Parcel Database ○ depreciated replacement value of structure ○ value of portion of contents damages from structure failure	Value of structures and contents lost during structure failure
Staircase Loss	Staircase value lost to bluff-top collapse	Parcel Database ○ exclude parcels with seawalls and parcels coded “Exclude”, include parcels with staircases Annual Erosion Rates ○ cumulative bluff-top land loss VAR ○ cumulative land loss before staircase is lost	Value of staircase lost to bluff-top erosion
Land Loss Bluff*	Value of land lost prior to structure collapse; valued as bluff-top	Parcel Database, Struct Failure or Parcel Loss ○ exclude parcels labeled “No-Value”, “Exclude”, and all parcels after structure failure Annual Erosion Rates, Parcel Database, VAR ○ linear feet of bluff-top land loss, parcel width, bluff-top land value per sq foot	Value of bluff-top land lost

Sheet	Purpose/Description	Inputs	Outputs
Land Loss non Bluff*	Land value lost if no structure is present or land value of remaining parcel during year of structure failure; valued as non bluff-top	Struct Failure of Parcel Loss, Parcel Database ○ determine parcels to exclude and include Annual Erosion Rates, Parcel Database, VAR, Year of Struct Failure ○ linear feet of land loss (or linear feet of remaining parcel length), parcel width, non bluff-top land value per sq foot	Value of non bluff-top land lost
Return Land Value*	Remove bluff-top land value premium: subtract bluff-top land value premium (difference between bluff-top and non bluff-top land value) for previous land lost on parcel at year of structure failure	Year of Struct Failure, Parcel Database ○ determine parcels to exclude and include Annual Erosion Rates, Parcel Database, VAR ○ cumulative linear feet of land erosion, parcel width, bluff-top premium per sq foot	Bluff-top premium for cumulative land area lost up to year of structure failure
Total Land Loss*	Calculates the total land value loss after adjusting for parcels that reverted from bluff-top value to non bluff-top value	Land loss bluff, land loss non bluff ○ value of land lost to bluff-top collapse (episodic events) Return Land Value ○ premium valuation of bluff-top land lost that has reverted to nonbluff top land lost	Total value of land lost after adjusting for parcels reverting from bluff top to non bluff top values
Total Damages	Sum the damages from lost land, lost staircases, and seawall construction and maintenance	Armored Constr. Armoring O&M Demolition Structure Damages Loss of Staircase Total Land Loss	Sum of the values from *Armoring Costr., Armoring O&M, Demolition, Structure Damages, Loss of Staircase, Total Land Loss*
PV Losses	Calculate the present value of the damages	Armored Constr. Armoring O&M Demolition Structure Damages Loss of Staircase Total Land Loss	Present value of *Armoring Costr., Armoring O&M, Demolition, Structure Damages, Loss of Staircase, Total Land Loss* by reach
Summary of Losses	Simplified presentation of total damages by reach from *PV Losses*	PV Losses	Present Value of total damages by reach
Annual Erosion Rates	Simulates bluff-top land loss based on initial toe notch depth	Erosion Rates (separate spreadsheet) ○ distribution of land erosion events dependent on toe notch depth Parcel Database ○ initial toe notch depth by parcel	Bluff-top land loss in linear feet
Setback Erosion	Derive structure setback distance from bluff-top during current year	Parcel Database ○ initial structure setback distance from bluff-top Annual Erosion Rates ○ bluff-top land loss in linear feet	Structure setback distance from bluff-top during current year
Parcel Erosion*	Derive remaining parcel length by year	Annual Erosion Rates	Parcel length remaining by year after erosion events

Sheet	Purpose/Description	Inputs	Outputs
Erosion Rates (separate spreadsheet)	Simulated probably distribution of bluff-top erosion dependent on initial toe notch depth and location within study area	n/a	Annual Erosion Rates sheet, bluff-top erosion for current year

**Sheets not present in Armoring Scenario*

3.3 Wave Force Damage Analysis

SPREADSHEET[14]
Wave Force Damage Analysis

3.3.1 Layout & Process

Wave Force Damage Analysis assesses the expected annual damages from return events (2-year to 100-year) given the probability of each return event occurring when tides are high enough to cause wave-overtopping. The two-year event is considered minor and causes partial road closures and minimal structure content damages. Five and ten-year events cause full road closures but minimal structure content damages. All other events are considered major and can cause full road closures and substantial structure and content damage.

In order for an event to cause wave force damages it must coincide with tidal conditions in the low-lying areas of Reach 7 only. All other reaches within the study area have bluff tops and are unaffected by wave force damages in the manner Reach 7 is impacted. The probability tidal conditions are suitable for a given return event to cause wave force damages is shown in the Prob Wave Exceedance sheet. These probabilities factor in the share of tidal conditions that meet or exceed the threshold for overtopping given each return event. As would be expected tidal conditions exceed this threshold more frequently under a 100-year event compared to a 2-year event and more frequently under the high sea-level rise scenario compared to the low. Damages from (1) travel delays and (2) structure damages & cleanup from each type of return event are shown in separate sheets. The EAD Wave Force Damages sheet combines the probability of wave exceedance, damages by return event, and probability of return event to determine the Expected Annual Damages. The stream of projected EAD values was discounted to a present value and annualized to derive an estimate of equivalent annual damages.

Table 3.3-1 Wave Force Damage Analysis Results (Low Sea-level Rise)

Return Event	Unadjusted Damages		Year	EAD
2	4,060		**2015**	17,203
5	13,461		**2025**	18,115
10	13,461		**2035**	19,030
25	838,679		**2040**	19,834
50	838,679		**2055**	20,762
100	838,679		**2064**	21,627

[14] A table describes the layout and function of Wave Force Damage Analysis at the end of this section.

For instance note the total damages for a 10-year event are $13,664 and $838,679 for a 25-year event. From the Prob Wave Exceedance sheet the probability of tidal conditions exceeding the height that would allow a 10-year return event to cause flooding is 22.05% in 2015 and under the low sea level scenario. This is multiplied by the total damages for a 10-year event, $13,664, to derive the calculation shown in cell E6 in the EAD Wave Force Damage sheet, $2,968. This process is repeated for the remaining return events (2, 5, 25, 50, and 100-year events). Next the average damages across return events are calculated by finding the difference between the probability of each pair of return event (e.g., the 10-year to 25-year pair is 10% - 4% = 6%) and multiplying this by the average damages between those same pairs of return events (e.g., $217,862/2 + $2,968/2 = $110,415). The sum of this set of calculations is the expected annual damages ($17,203 in 2015). These calculations are done for each return event for all 50 years of the study period, then summed and discounted to determine the net present value and annualized to estimate the equivalent annual damages for low and high sea-level rise scenarios shown in EAD Flooding and VAR sheets.

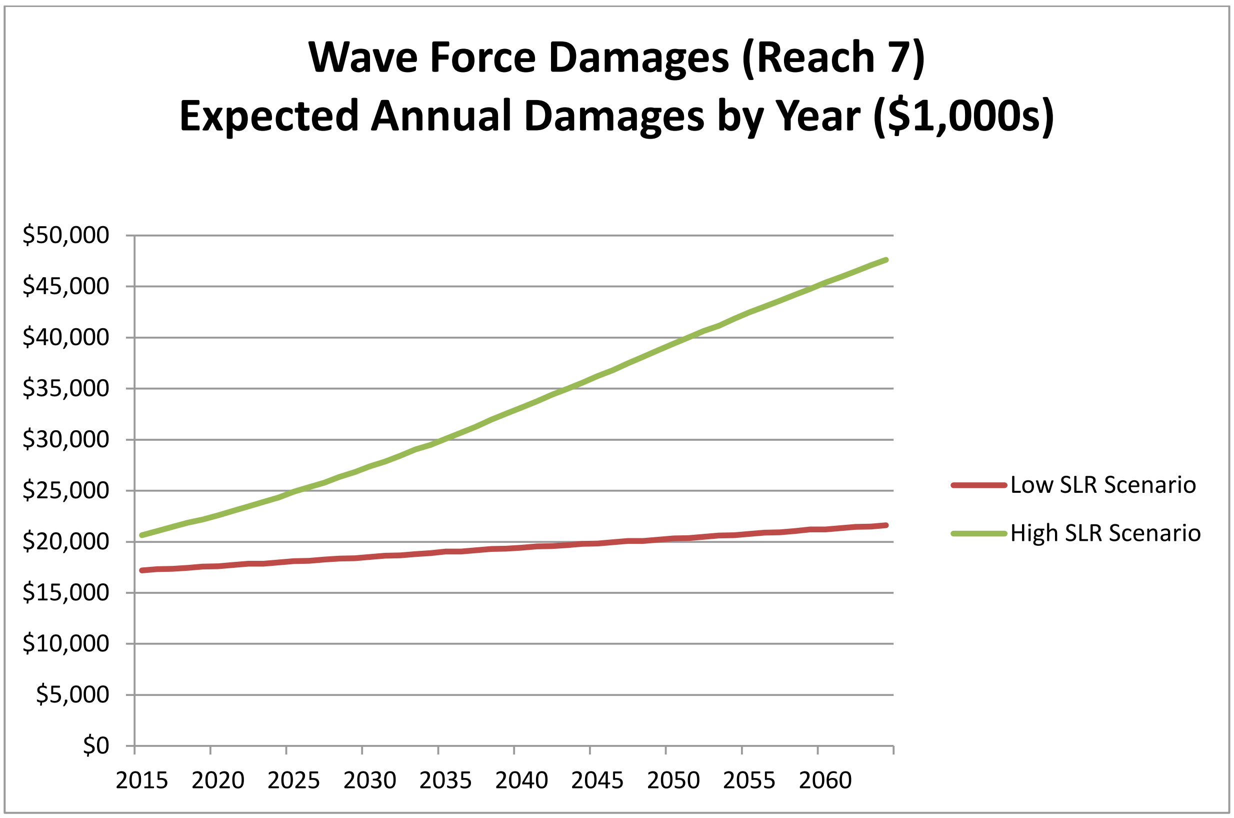


Figure 3.3-1 Wave Force Damages (Reach 7) - Expected Annual Damages by Year ($1,000s)

Table 3.3-2 WAVE FORCE DAMAGE ANALYSIS BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet Name	Purpose/Description	Inputs	Outputs
VAR	Key assumptions used to derive damages due to travel delay & structure flooding	Median income, traffic volume, occupants per vehicle, trip purpose, rerouting distance, variable vehicle costs	n/a
Travel Delay	Compute value of additional travel time and travel distance for partial and full roadway closures	VAR ○ additional travel distance, time ○ share of vehicles by purpose ○ median hourly wage ○ value of time saved adjusted to percent of driver family income by trip purpose	Value of additional travel time; value of additional travel distance
Structure & Cleanup Damages	Damages to structure contents by category, roadway cleanup costs	Content values from 2005 draft report Roadway cleanup costs from 2005 draft report at 2010 price levels	Damages to structure contents and roadway cleanup costs for minor and major storm surge events
Damages	Average Damages from storm events and Expected Annual Damages before adjusting for wave-overtopping probabilities; EAD from return events	Structure & Cleanup Damages	Expected Annual Damages by return event before adjusting for wave-overtopping probabilities
Prob wave Exceedence	Probability of wave overtopping for return events over time and high and low sea-level rise scenarios	n/a	n/a
EAD Wave Force Damages	Expected Annual Damages after adjusting for wave overtopping probabilities; EAD from flooding	EAD Return Event Prob of wave exceedance	Expected Annual Damages from flooding

3.4 Recreation Analysis

SPREADSHEETS[15]

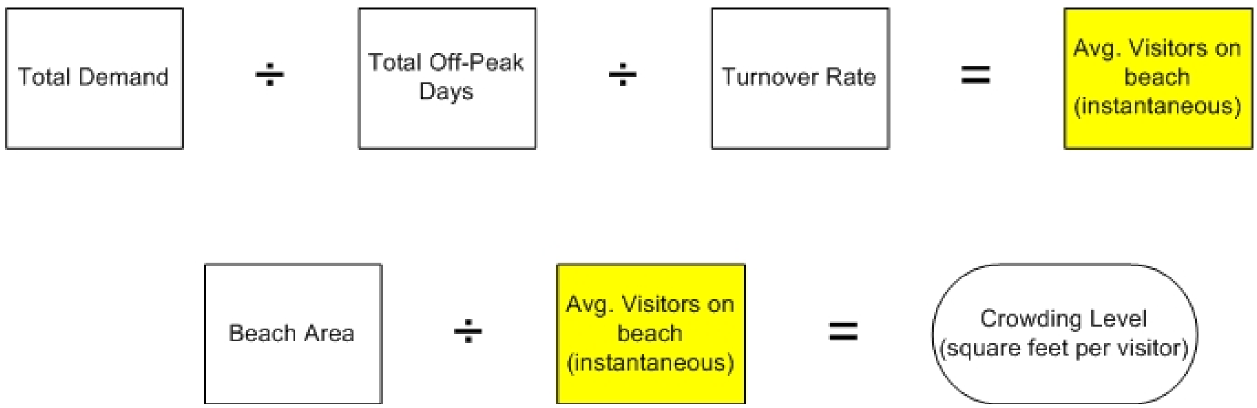
Recreation Analysis Without Project *Recreation Analysis Without Project & With RSBP II Alt 1*
Recreation Analysis Without Project & With RSBP II Alt 2

3.4.1 Benefit Estimation Technique

Recreation Analysis assesses with and without project recreation benefits by using the Unit Day Value method as outlined by ER1105-2-100 and IWR Report 86-R-4. The Unit Day Value sheet in *Recreation Analysis* lists a range of values that consider the characteristics of the study area beaches and the level of crowding. Unit Day Values were assigned using the "Guidelines for Assigning Points for General Recreation" from EGM #11-03 and in consideration of expert opinion by two local lifeguards. These values are applied to all demand for beach recreation. First demand is met by visitations to the dry beach. These visitations are distributed among off peak days, peak weekdays, and peak weekends and assigned unit day values based on the average level of crowding (square feet per visitor). To derive the Crowding Level during the off-peak season, for instance, the total visitation demand during off-peak season is divided by the number of off-peak days to determine the average visitors per day. Then the average visitors

[15] A table describes the layout and function of the Recreation Analysis spreadsheet at the end of this section.

per day is divided by the turnover rate to determine the average number of visitors on the beach at any moment. Finally the beach area is divided by the average visitors on the beach at any moment to determine the level of crowding (square feet per visitor). The Crowding Level is not allowed to exceed 30 square feet per person on the dry beach (cell K2 in Rec Values – DRY BEACH sheet). When there is excess demand that would lead to crowding beyond this cut-off, it is transferred to the wet beach.



Example of how to calculate crowding level for ‘off-peak’ (winter) days. Calculating ‘peak’ demand days simply involves adding up the days and replacing *Total Off-Peak Days* with *Total Peak Days*. Once ‘crowding level’ is calculated the final step to value recreation involves applying the correct Unit Day Value and multiplying it by the number of beach visitors.

3.4.2 Wet Beach recreation

Visitors transfer to the wet beach rather than go to an off-site dry beach because historical attendance patterns show visitations have occurred on wet beaches, particularly during the winter when the beach area is smaller due to seasonal variations. The amount of dry to wet beach transfers are calculated on the DRY BEACH sheet but the recreation values from these wet beach transfers are derived in the WET BEACH sheet. The visitors that transfer from the dry to wet beach are located in rows 107 to 135 of Rec_Values – DRY BEACH sheet. These wet beach transfers carry over to the Rec_Values – WET BEACH sheet between rows 32 and 52, Winter and Summer Demand. Once visitors transfer to the wet beach, the same process used on the dry beach is used to determine the level of crowding on the wet beach. However, all wet beach attendees are given one fixed unit day value regardless of the level of crowding. That value, given in cell K1, is below the minimum dry beach unit day value. Another difference is tolerance for crowding on the wet beaches compared to dry beaches (see cell K2 of each respective sheet). When overcrowding occurs on the wet beach, potential visitors transfer to an off-site beach. The net gain from this transfer is assumed to be the lowest unit day value, $3.58, and is applied to all off-site transfers.

3.4.3 Sea-Level Rise and Beach Erosion

Sea-level rise reduces the available beach area to recreate throughout time. This impact is addressed in the Erosion Seg1 &2 sheets starting in column AT. Segments 1 & 2 have been broken down by their respective reaches since historical beach visitation has been compiled by reach. As expected the high sea-level rise scenario causes more rapid beach loss than the low sea-level rise. These losses impact the dry beach first if present. While the dry beach is eroding, the wet beach maintains its size. When the dry beach is gone, the wet beach area is reduced in the same manner as the dry beach. All else held constant beach erosion causes recreation to transfer from the high-value dry beach to low-value wet beach and off-site beach.

Table 3.4-1 RECREATION ANALYSIS BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet Name	Purpose/Description	Inputs	Outputs
Rev_Values – DRY BEACH	Value recreation experience on dry beaches in study area; calculate number of transfers from dry beach to wet beach	*Given* ○ Daily visitor turnover ○ Weekday & weekend distribution of visitors ○ Peak week & weekend days, off peak days ○ Turn away/overcrowding point in square feet per visitor UDV ○ Range of values for dry beach recreation per visitation dependent on level of crowding EROSION SEG 1/2 ○ Reduction in dry beach area due to low and high SLR	Remaining dry beach area, recreation demand, capacity to meet demand, visitations, transfers to wet beach, square feet per visitor, UDV per visitor, annual recreation value by reach
Rec_Values – WET BEACH	Value recreation experience on wet beaches in study area; value recreation experience gain to off-site transfers	Rec_Values – DRY BEACH ○ Transfers from dry beach to wet beach, determine when dry beach begins to disappears due to low and high SLR UDV ○ Fixed value for wet beach recreation per visitation Area ○ Reduction in wet beach area due to low and high SLR and after dry beach disappears *Given* ○ Turn away/overcrowding point in square feet per visitor	Remaining wet beach area, recreation demand, capacity to meet demand, visitations, transfers to off-site beach, square feet per visitor, UDV per visitor, annual recreation value by reach
Erosion Seg 1	Change in beach width to Segment 1 (reaches 3-5)	Erosion rate of beach widths for Segment 1 (reaches 3-5) and sea-level rise scenario	n/a
Erosion Seg 2	Change in beach width to Segment 2 (reaches 3-5)	Erosion rate of beach widths for Segment 2 (reaches 3-5) and sea-level rise scenario	n/a
Demand	Apply forecasted recreation demand growth to historical attendance; growth mirrors projected San Diego county growth	Attend_Historical	Forecasted growth in recreation demand
UDV	Unit Day Value; range of points and corresponding unit day values for various levels of crowding at the study area beaches	Unit Day Value points	Unit Day Values by level of crowding on beach (available square feet per visitor)
Attend_Historical	Historical attendance data provided by local sponsors and used to forecast future attendance	n/a	n/a

3.5 RSBP II Impact

SPREADSHEET[16]

RSBP II Analysis	*Recreations Analysis WITHOUT Project & WITH RSPB II, alt 1/2*

3.5.1 Process & Layout

Regional Sand Beach Placement II (RSBP II) is a local, opportunistic sand nourishment project organized and funded by the San Diego Area Governments (SANDAG). RSBP II will occur in both study area communities in 2012, three years before the USACE project, and is assumed to be a one-time occurrence. RSPB II was analyzed because it is likely to occur and measurable per ER-1105-2-100 guidelines. In addition sand volume in the system under without project conditions does not provide storm damage reduction benefits unless sand volume from RSBP II is included in the evaluation. When RSBP II is considered part of the without project conditions then the sand volume in the system does provide modest coastal storm damage reduction benefits that overlaps with the initial portion of USACE study period.

RSBP II impacts Segment 1 and 2 differently. Segment 1 has one viable fill alternative and Segment 2 has two viable fill alternatives labeled “Alternative 1” and “Alternative 2”. The fill alternatives were given in sand volumes that have been translated to beach widths by USACE coastal engineers. Erosion rates by feet of beach width per year have also been provided by coastal engineers. These values can be found in the VAR sheet. From this information the average remaining beach width was calculated from the USACE base year until the end of the study period (2015-2064). Finally, after considering residual sand in the system with RSBP II in place, the remaining beach widths were analyzed for any storm damage reduction benefits. In a later step these will be subtracted from the storm damage reduction benefits from each USACE project alternative.[17]

The process to arrive at the partial storm damage reduction benefits under without project conditions (including RSBP II) mirrors the process applied to with project conditions. Essentially sand volume in the system offers partial protection from coastal damages. Sand volume is translated into beach width and the Partial Benefits Capture Curve shown in VAR sheet rows 58 to 127 shows the percent of storm damages that can be captured for a given beach width.[18] Cell D2 in the IMPACT SEG 1/2 sheet shows the storm damage reduction benefits (derived from weighting the *Armoring* and *Retreat Scenarios* just as in B-C Analysis) Next this amount is adjusted downward based on the partial benefits sand in the system can offer according to the Partial Benefits Capture Curve. The results are shown in IMPACT SEG 1/2 sheets, rows 16 to 17, under the heading “Partial Storm Damage Benefits.” In this manner the same Partial Benefits Capture Curve and method were applied to analyze with and without project conditions.

Recreation Analysis Without Project & With RSBP II is the without project conditions including the projected impacts of RSBP II. It is located in the Recreation Analysis folder and calculates the recreation values with RSBP II in place that occur during the USACE study period. Because this fill causes the without project beaches to become wider and maintain that width further into the study period than would otherwise occur, the recreation values are higher with RSBP II

[16] A table describes the layout and function of each sheet in RSBP II Analysis at the end of this section.
[17] See B-C Analysis in *With Project Conditions* section for an explanation of how the without project conditions from with project SDRB.
[18] See B-C Analysis in With Project Conditions section for an explanation of how the partial storm damage reduction benefits were derived.

included in the without project conditions. Therefore the recreation benefits that include the impacts of RSBP II have been calculated as well as the recreation benefits without considering the impacts of RSBP II. Later these benefits are deducted from the benefits under the USACE with project conditions to determine the additional recreation benefits of each USACE project alternative (see *With Project Conditions* section for more details.)

3.5.2 Reduced Initial Fill Costs

Offsetting this reduction in the USACE storm damage reduction benefits is savings from less initial sand fill volume for the USACE project alternative. This is because sand volume from RSBP II will remain in the system several years beyond 2015, the USACE base year. The exact amount of residual sand volume remaining in 2015 differs by segment and alternative. This extra sand volume in the base year means the USACE project alternative will need less sand volume for the initial fill in 2015. The amount of reduced sand fill volume is shown *RSBP II Analysis* spreadsheet, IMPACT SEG 1/2 sheets in cell E39. It is subtracted from the USACE project alternative initial fill in the *B-C Analysis* spreadsheet.

3.5.3 Impact to USACE Project Alternatives

The final step is to account for changes to without project conditions with the addition of RSBP II. This is done in the *BC Analysis* spreadsheet RECREATION sheet and the BC SUM SEG1/2 sheets by subtracting coastal storm damage benefits and initial fill cost savings attributable to RSBP II. In all other manners the benefits and costs for each project alternative are identical in calculation and presentation to the benefits and costs calculations done without consideration of the impact to RSBP II.

Table 3.5-1 RSBP II ANALYSIS BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet	Purpose/Description	Inputs	Outputs
VAR	Present key assumptions/inputs in one sheet	n/a	n/a
IMPACT SEG 1	Calculate the partial coastal storm damage protection after considering the impact from RSBP II on Segment 1; calculate residual sand fill volume that occurs in the USACE base year	VAR o Beach width erosion rates based on low and high sea-level scenarios o Maximum potential storm damages protection o Partial benefits capture curve o Variable costs of beach fill	Without Project conditions for Segment 1 including impacts of RSBP II— modest coastal storm damage protection due to limited sand volume in system from USACE base year, 2015, until sand leaves system
IMPACT SEG 2 Alt 1	Calculate the partial coastal storm damage protection after considering the impact from RSBP II on Segment 2 and Alternative fill 1; calculate residual sand fill volume that occurs in the USACE base year	VAR o Maximum potential storm damages protection o Partial benefits capture curve o Variable costs of beach fill o Beach width erosion rates based on low and high sea-level scenarios	Without Project conditions for Segment 2 including impacts of RSBP II Alt 1— modest coastal storm damage protection due to limited sand volume in system from USACE base year, 2015, until sand leaves system
IMPACT SEG 2 Alt 2	Calculate the partial coastal storm damage protection after considering the impact from RSBP II on Segment 2 and Alternative fill 2; calculate residual sand fill volume that occurs in the USACE base year	VAR o Beach width erosion rates based on low and high sea-level scenarios o Maximum potential storm damages protection o Partial benefits capture curve o Variable costs of beach fill	Without Project conditions for Segment 2 including impacts of RSBP II Alt 2— modest coastal storm damage protection due to limited sand volume in system from USACE base year, 2015, until sand leaves system
Recreation Analysis without project & with/without RSBP II [separate spreadsheets]	Determine the to recreation values when considering from the impact from RSBP II	VAR o Beach width erosion rates based on low and high sea-level scenarios o Maximum potential storm damages protection o Partial benefits capture curve o Variable costs of beach fill	Recreation values without USACE project and with/without RSBP II

4 With Project Conditions

SPREADSHEETS

*B-C Analysis** *Sloughing Damage Analysis**

Recreation Analysis With Project (2/16 – year renourish interval)

*Excel Add-in @RISK must be running

4.1 Layout & Process

The with-project alternatives capture the benefits from the reduction in coastal damages modeled under without-project conditions—*Armoring & Retreat Scenarios* and *Wave Force Damage Analysis*—as well as increased recreation benefits from maintaining larger beaches—*Recreation Analysis with Project*. *Armoring* and *Retreat Scenario* are weighted according to the probability of each scenario occurring. This determines the expected damages and the maximum possible benefits under the with-project alternatives. The maximum benefits may or may not be achieved depending on the amount of coastal protection each alternative offers. *BC Analysis* calculates the partial coastal protection benefits of each project alternative. Similarly *Wave Force Damage Analysis* shows the maximum possible benefits under the with-project alternative and may not be achieved under all possible alternatives. *Recreation Analysis with Project* determines the recreation values under each project alternative. After *Recreation Analysis without Project* is deducted, the remainder is the recreation benefits from each project alternative.

4.2 Weighting Armoring & Retreat Scenario

Armoring and Retreat Scenario model two mutually exclusive behavior patterns of parcel owners that result in differing amounts of without project coastal storm damages. *Armoring Scenario* assumes all owners threatened by structure failure/collapse are able to construct seawalls in time. *Retreat Scenario* assumes these same owners are unable to construct seawalls in time and the first row of structures collapse. Since which owners will be able to respond in time to construct a seawall is not known, both scenarios have to be weighted. Weighting the Armoring and Retreat Scenario involves establishing the percentage of "unexpected" and "threatening" bluff-top collapses that can lead to structure failures. "Threatening events" are bluff top collapses that occur when the structure setback distance is between 25 and -5 feet, which is a range of distances that leave the structure vulnerable to the next episodic event. Parcels that experience threatening events may experience erosion events the following year that cause structure failure and these are called "unexpected events." Unexpected events happen when setback distances greater than 0 feet are followed immediately the next year by episodic events that cause the setback distance to be less than -5 feet, which is the minimum setback distance that causes structure failure. The percentage of "unexpected events" to "threatening" and "unexpected" events is the basis for the minimum possible weighting for *Retreat Scenario*. After establishing this minimum weighting, it was adjusted upward by 15% based on subjective considerations for owners that do not have the financial means or timely construction permits to build seawalls in time as well as those that do not construct seawalls in time for other personal reasons. Therefore the minimum weighting, which differs by segment and sea-level rise scenario, was increased by 15% based on subjective criteria to finally arrive at the adjusted weighting that is applied to *Retreat & Armoring*

Scenarios to calculate the expected without project damages.[19] The minimum and adjusted weighting results are shown in the table below.

	Minimum Weighting (objective consideration of "unexpected" episodic events only)		Adjusted Weighting (subjective consideration of financial, regulatory, and personal factors of owners)	
	Low SLR	**High SLR**	**Low SLR**	**High SLR**
Segment 1 (Encinitas)	2.9%	5.1%	18%	20%
Segment 2 (Solana Beach)	6.9%	14.1%	22%	29%

4.3 PROJECT BENEFITS: Realized/Partial Reduction to Coastal Damages[20]

Although the *Armoring and Retreat Scenarios* give the maximum possible reduction in coastal damages, the actual reduction depends on the amount of coastal protection each alternative provides. This protection is quantified in the "Partial Benefit Capture Curve," which defines the relationship between the mean sea level beach width and the percentage of potential benefits realized from protecting the toe of the bluff from coastal storm erosion. The Partial Benefit Capture Curve is found in the *BC Analysis* Component VAR sheet. A separate Benefits Capture Curve was derived for each of the two communities and covers reaches 3-5 and 8-9, respectively. Applying the percentage of potential benefits taken from the benefits capture curve to the maximum preventable damages, which is based on weighting the retreat and armoring scenarios and then accounting for residual sloughing damages, is the method to determine the realized benefits for each project alternative. Therefore the steps to determine the project alternative benefits are:

1) Determine without project damages for *Armoring & Retreat Scenarios*
2) Weight *Armoring & Retreat Scenarios*
3) Subtract Sloughing (Residual) With Project Damages
4) Establish Remaining Preventable Damages
5) Apply Benefit Capture Curve to determine percent of Remaining Preventable Damages each project alternative captures (i.e., project alternative benefits)

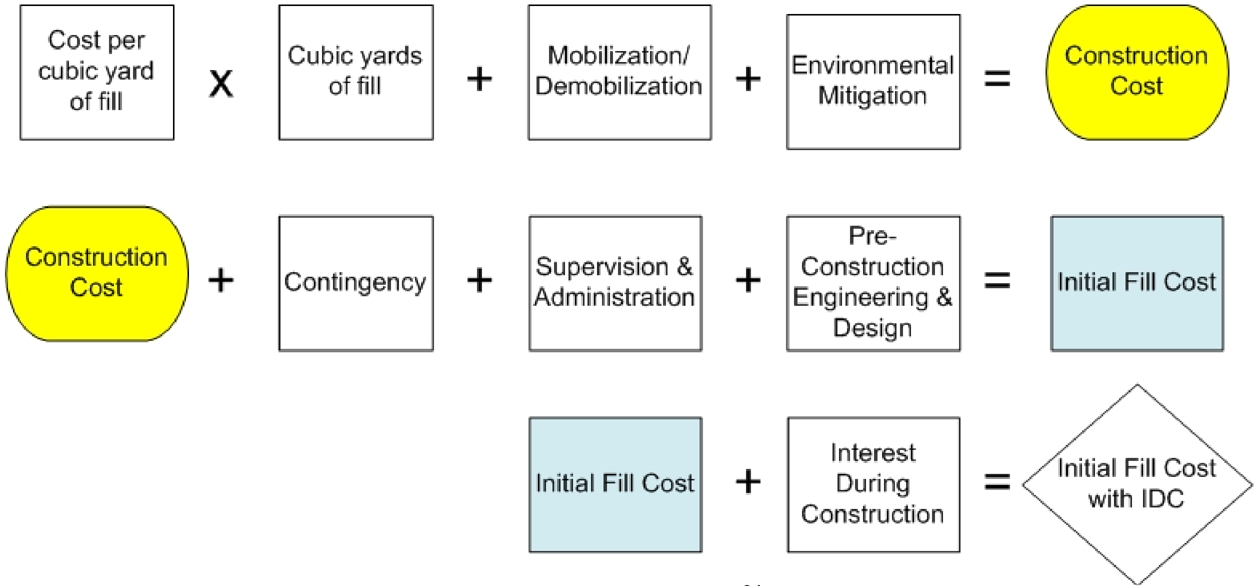
4.4 PROJECT COSTS: Initial & Renourishment Costs

The with-project costs for beach replenishment are found in *BC Analysis*, COST SEG1/2 sheets. The costs are mobilization and demobilization of equipment, pre-construction engineering & design, supervision & administration, operation & maintenance, monitoring, environmental mitigation, contingency, and cost per cubic yard of sand fill. The initial fill and subsequent renourishment cycles are calculated somewhat differently.

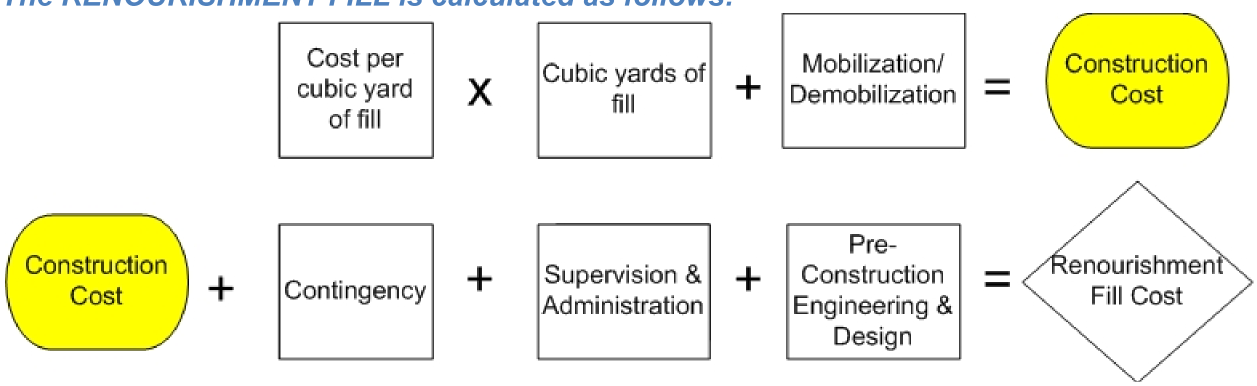
[19] *Sloughing (Residual) Damages* are subtracted after the expected without project damages have been calculated to arrive at the Remaining Preventable Damages. See the *Sloughing Damage Analysis* section for further details.

[20] With project benefits are estimated with a benefit capture curve. This curve defines the relationship between the mean sea level (MSL) beach width and the percentage of potential benefits realized from protecting the base of the bluff from coastal storm erosion. See *Encinitas and Solana Beach Benefit Curve Rationale* dated 8/1/2008 for further explanation.

The INITIAL FILL is calculated as follows:



The RENOURISHMENT FILL is calculated as follows: [21]



Once the initial fill cost and subsequent renourishment costs have been calculated by year the final step involves discounting all these costs, calculating the present value cost for monitoring and operation & maintenance, and adding each together to determine the net present value for each alternative fill and renourishment cycle combination. This gives the total costs during the study period for each project alternative and replenishment cycle as net present value. Construction costs are presented in the year they occur within the study period across all fifteen possible replenishment cycles. This creates a matrix of replenishment cycles from two years to sixteen years for each project alternative. For instance the 50-foot Project Alternative is presented in rows 8 to 70 of the COST SEG 1/2 sheets. Each replenishment cycles is a separate column with Total Initial Fill Cost appearing in row 16, the first year of the study period 2015, and subsequent renourishment fill costs appearing in later years. These costs are summed and discounted in row 67, NPV, then the net present value of monitoring and operation & maintenance are summed to arrive at the Total NPV Costs, row 70.

[21] Note Renourishment Fill had to be calculated within a single excel formula. Contingency is a percentage of Construction Costs therefore the calculation to arrive at Construction Costs plus Contingency within a single spreadsheet cell is (1+Contingency %) x Construction Costs. Supervision & Administration is also a percentage of Construction Cost plus Contingency so, again, the formula within a single cell is (1+S&A %) x Construction plus Contingency Costs. PED is handled in the same manner. The result of these calculations is the same had Contingency, S&A, and PED been calculated on separate lines then added as shown in the formula visual above.

4.5 Recreation Analysis

SPREADSHEETS[22]

Recreation Analysis With Project (2-year renourish interval) … *Recreation Analysis With Project (16-year renourish interval)*

4.5.1 Layout & Process

Recreation Analysis with Project calculates recreation values using the same method as *Recreation Analysis without Project*. First demand and beach area are established to determine the maximum visitation capacity of each dry beach by peak and off-peak seasons. Demand that exceeds this dry beach capacity is transferred to the wet beaches at a lower, fixed unit day value. Finally any excess demand on the wet beaches transfers to an off-site beach and is given the lowest recreation value. For a more detailed explanation of this process see the earlier *Recreation Analysis without Project* description.

4.5.2 Growth in Demand

Recreation Analysis with Project incorporates increased recreation opportunities due to larger, maintained beach areas. To accommodate this three sheets not present in the without project component have been added, namely, *Demand Growth*, *Alternatives SEG 1*, and *Alternatives SEG 2*. The Demand Growth sheet projects the increased recreation demand from each of the project alternatives. Based on guidance from IWR Report 86-R-4[23], the Similar Project Method was used to estimate additional recreation demand created by the project alternatives. "The similar project method involves comparing certain characteristics of the proposed project with those of a bank of existing water resources projects for which use statistics and other information have been compiled. The most efficient and technically sound similar project techniques are those which provide for the development of per capita use curves from which use estimates are then indirectly derived." To this end use statistics for two nearby and similar beaches in Carlsbad and Oceanside were obtained.[24] Next per capita (beach) use curves were created by comparing use statistics (i.e. the share of beach visitors traveling various distances to get to the beach) to populations within each city, outside each city but within 20 miles, 20 to 60 miles, and more than 60 miles. Once the per capita beach visitors willing to travel these various distances is known for the similar project beaches, this result was adjusted per guidance before being applied to the study area beaches in Encinitas and Solana Beach. The adjustment is necessary due to (1) inherent dissimilarities between these similar-project beaches and the study area beaches despite close proximity, similar surrounding populations, and similar beach widths with a USACE project alternative in place and (2) insufficient data to develop a gravity model or use other methods of statistical control for dissimilar characteristics. This adjustment was made under the column heading "Adjusted Per Capita Day Use by Location" (column G in Demand Growth sheet). The range of project alternatives results in substantially different beach widths from 50 feet of additional beach width to 200 feet and the adjusted per capita use curve adjusts across this range of alternatives.

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[22] A table describing the layout and process of Recreation Analysis is located at the end of this section.

[23] IWR Report 86-R-4 *National Economic Development Procedures Manual - Recreation Volume I: Recreation Use and Benefit Estimation Techniques*.

[24] "Use Statistics" relevant to this analysis are beach attendance and the share of attendees traveling various distance to get to Carlsbad and Oceanside beaches. Use statistics were obtained for Carlsbad beaches from *The Economics and Fiscal Impact of Carlsbad Beaches* by Dr. Philip King (2005) and for Oceanside beaches from *US Army Corps of Engineers Beach Attendance Survey* (2005)

The statistics used and calculations performed to arrive at the with-project demand using the similar project approach are located on the Demand Growth sheet, rows 3 to 24. Among the project beaches Carlsbad was selected as the best analogue to Solana Beach and Oceanside as the best analogue to Encinitas. Use statistics from Carlsbad showed a majority of beach visitors came from within the city or up to 20 miles away. Use statistics from Solana Beach several years earlier showed a similar but even larger majority than in Carlsbad traveled no more than 20 miles to visit its beaches. As the beaches of Solana Beach exist now, they can be categorized a “localized” attraction to visitors of the community and nearby cities. Carlsbad also has a large share of “local” visitors but is more balanced by the larger share traveling 20 or more miles to visit. This makes Carlsbad a better analogue to Solana Beach. In contrast Encinitas has recently attracted about 3 million visitors to its beaches annually while its modest number of residents can only be a small share of those annual visits.[25] This makes Encinitas' beaches more comparable to Oceanside, which hosts twelve percent of visits from within the city and a large share, sixty percent, from distances of 20 miles or greater.

Again, while Carlsbad and Solana Beach as well as Oceanside and Encinitas showed many similarities including similar-sized communities, similar usage-distance patterns, close proximity, and similar with-project beach widths (approximately 190 feet in the similar project beaches chosen for this analysis), many uncontrolled factors/dissimilarities had to be accounted for through quantitative and qualitative adjustments to the per capita use curves before this could be applied to Solana Beach and Encinitas as specified in the guidance.

Once the projected recreation demand was estimated using the similar project method, it was separated by reach so that this demand could be incorporated in to the recreation values calculated in Rec_Values – DRY BEACH and Rec_Values – WET BEACH sheets. The steps used to separate demand by reach are shown in the Demand Growth sheet, rows 27 to 44. For Solana Beach the entire study area is within the placement of alternative beach renourishments. The projected demand was split according to historical attendance patterns by season and reach. For Encinitas reaches 3-5 overlap with the placement of beach renourishments and a reasonable amount of long shore sand movement so only these reaches experience the projected increase in demand (shown in blue text and italicized in Demand Growth sheet). Since sand fill is only placed within reaches 3-5 while the city of Encinitas extends from reach 1 to 7 that means about two-thirds of the study area is outside the placement of the alternative beach renourishments and roughly two-thirds of the visits occur outside those placement areas. To capture this only one-third of the projected increase in demand within Encinitas (roughly 200k of the 600k total projected increase in with-project demand) was used to calculate the increased recreation benefits as shown in Rec_Values – DRY BEACH and WET BEACH sheets.

The other additional sheets not present in the without project Recreation Benefits component are Alternatives SEG 1 and Alternatives SEG 2 sheets. Each sheet is laid out identically except that SEG 1 falls within reaches 3-5 in Encinitas and SEG 2 falls within reaches 8-9 in Solana Beach where the beach renourishments occur. Each sheet shows the averaged net beach width change from the project alternatives after placing 50 feet to 200 feet of initial fill down and allowing 1 to 16 years between renourishment cycles. For example row 14 of Alternatives SEG

[25] The exact share of attendance by distance from Encinitas is unknown because those statistics are not available.
However, we know the use statistics for nearby beach communities and can reasonably conclude that since Encinitas has about 64,000 residents no more than several hundred thousand of the 3 million annual beach visits can be attributed to its residents. The vast majority would have to come from areas outside Encinitas, which is comparable to Oceanside's use statistics.

1 sheet shows that five years after the 50-foot beach renourishment there is 19.7 feet of averaged remaining net beach. After eleven years there is only 1 foot remaining.

Table 4.5-1 RECREATION ANALYSIS WITH PROJECT BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet Name	Purpose/Description	Inputs	Outputs
Rev_Values – DRY BEACH	Value recreation experience on dry beaches in study area; calculate number of transfers from dry beach to wet beach	*GIVEN* ○ Daily visitor turnover ○ Weekday & weekend distribution of visitors ○ Peak week & weekend days, off peak days ○ Turn away/overcrowding point in square feet per visitor UDV ○ Range of values for dry beach recreation per visitation dependent on level of crowding Area ○ Reduction in dry beach area due to low and high SLR	Remaining dry beach area, recreation demand, capacity to meet demand, visitations, transfers to wet beach, square feet per visitor, UDV per visitor, annual recreation value by reach
Rec_Values – WET BEACH	Value recreation experience on wet beaches in study area; value recreation experience gain to off-site transfers	*GIVEN* ○ Turn away/overcrowding point in square feet per visitor Rec_Values – DRY BEACH ○ Transfers from dry beach to wet beach, determine when dry beach begins to disappears due to low and high SLR UDV ○ Fixed value for wet beach recreation per visitation Area ○ Reduction in wet beach area due to low and high SLR and after dry beach disappears	Remaining wet beach area, recreation demand, capacity to meet demand, visitations, transfers to off-site beach, square feet per visitor, UDV per visitor, annual recreation value by reach
Area	Beach area for recreation lost to sea-level rise	Reduction in beach area under low and high sea-level rise scenarios by reach Initial mean-sea level (MSL) beach area and wet & dry beach area by reach	n/a
Demand	Apply forecasted recreation demand growth to historical attendance; growth mirrors projected San Diego county growth	Attend_Historical	Forecasted growth in recreation demand
Demand Growth	Apply Similar Project Method to estimate increased recreation demand with project alternatives in place	Travel distance by share of visitors Annual beach attendance at Carlsbad and Oceanside beaches Population by community in San Diego and Southern Orange & Riverside Counties	Estimated recreation demand by reach with project alternatives

Sheet Name	Purpose/Description	Inputs	Outputs
UDV	Unit Day Value; range of points and corresponding unit day values for various levels of crowding at the study area beaches; points assignment informed based by local expert assessment of five criteria	Unit Day Value points	Unit Day Values by level of crowding on beach
Alternative SEG 1	Provide averaged net beach width changes in Encinitas for each project alternative with zero to sixteen years between renourishment cycles	n/a	n/a
Alternative SEG 2	Provide averaged net beach width changes in Solana Beach for each project alternative with zero to sixteen years between renourishment cycles	n/a	n/a
Attend_Historical	Historical attendance data provided by local sponsors and used to forecast future attendance	n/a	n/a

4.6 Sloughing (Residual) Damage Analysis

SPREADSHEETS

Sloughing Damage Analysis[26] *Erosion Rates_sloughing*

4.6.1 Layout & Process

With any of the alternatives in-place residual sloughing will occur in unstable areas until a stable angle of repose is achieved. Geotechnical analysis estimated the annual natural sloughing rates in unstable, unprotected areas of the study and this has been quantified in the *Erosion Rates_sloughing* spreadsheet. These annual sloughing rates are inputted in the Sloughing Damage Analysis spreadsheet, Annual Erosion Rates sheet to calculate annual land erosion rates due to sloughing. The Land Loss sheet takes these land erosion rates, which are in linear feet, and multiplies them by the affected parcel width to come up with land area lost. Finally this area is multiplied by the cost per square foot of bluff top land found in the VAR sheet. A summary of these losses are presented in the PV Losses and Summary of Losses sheets. An explanation of each sheet of the Sloughing Damage Analysis Component can be found in the table below.

[26] Excel Add-in @RISK must be running

Table 4.6-1 SLOUGHING DAMAGE ANALYSIS BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet	Purpose/Description	Inputs	Outputs
VAR	Present key assumptions/inputs in one sheet	Bluff-top land loss value, iteration number to pull data from Erosion Rates sheet [separate spreadsheet]	n/a
Parcel Database	List all bluff-top parcels in Encinitas and Solana Beach with setback distance, parcel & structure area, structure value, toe depth	Area MFR&condos ○ condo & duplex area M&S ○ construction quality & condition valuations from Marshall & Swift	Structure depreciated replacement values
Area MFR&condos	Area of condos and duplexes by housing unit	n/a	n/a
M&S	Structure value per square foot by housing type, construction quality, and condition	Marshall & Swift Valuation Guide	n/a
Land Loss	Value of land lost prior to structure collapse; valued as bluff-top	Annual Erosion Rates, Parcel Database, VAR ○ linear feet of bluff-top land loss, parcel width, bluff-top land value per sq foot	Value of bluff-top land lost
PV Losses	Calculate the present value of the damages due to sloughing at bluff top	Total Land Loss	Present value *Total Land Loss* by reach
Summary of Losses	Simplified presentation of total damages by reach from *PV Losses*	PV Losses	Present Value of total damages by reach
Annual Erosion Rates	Simulates bluff-top land loss based on initial toe notch depth	Erosion Rates [separate spreadsheet] ○ distribution of land erosion events dependent on toe notch depth Parcel Database ○ initial toe notch depth by parcel	Bluff-top land loss in linear feet
Parcel Erosion	Derive structure setback distance from bluff-top during current year	Parcel Database ○ initial structure setback distance from bluff-top Annual Erosion Rates ○ bluff-top land loss in linear feet	Structure setback distance from bluff-top during current year
Toe Depths		Notch Erosion Rates [separate spreadsheet] Parcel Database ○ initial toe depths	Toe depth for current year
Erosion Rates_sloughing [separate spreadsheet]	Simulated probably distribution of bluff-top erosion dependent on initial toe notch depth and location within study area	n/a	Annual Erosion Rates sheet, bluff-top erosion for current year

4.7 Reduction in Storm Damage Benefits & Benefit Cost Analysis

SPREADSHEET[27]
B-C Analysis[28]

4.7.1 Layout & Process

B-C Analysis determines the net benefits of each project alternative by subtracting the costs from the benefits for each combination of fill alternative and replenishment/renourishment interval. The flow chart shown above outlines how to arrive at these cost and benefits. First without project damages from *Retreat* and *Armoring (Seawall) Scenario* are weighted and combined then *Sloughing Damages* are subtracted. Next the partial benefits curve is applied to arrive at the partial reduction in storm damages benefits of the project alternatives (Total With Project Benefits). Finally the project alternative costs are subtracted to arrive at the net benefits for each project alternative and the NED plan.

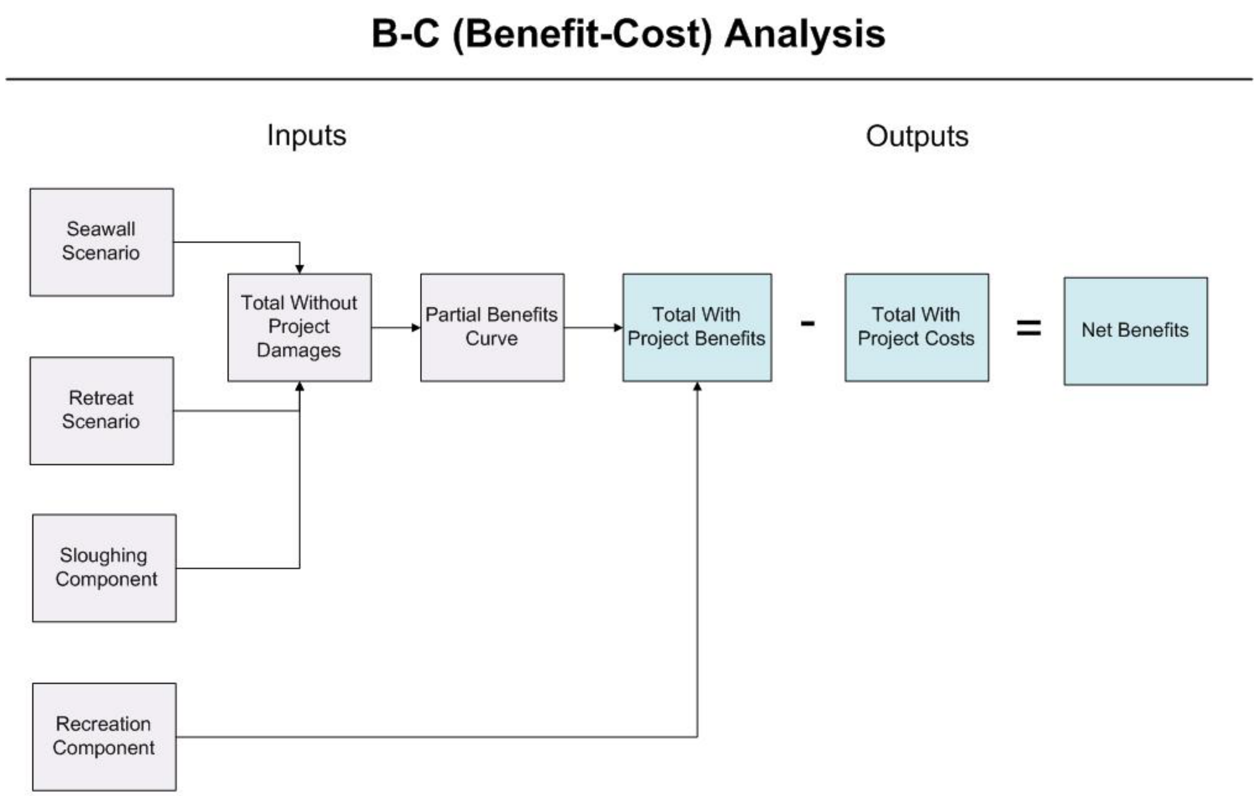

Figure 4.7-1 B-C (Benefit-Cost) Analysis

4.7.2 Deriving Realized/Partial Coastal Damage Benefits

To determine the realized coastal damage benefits, the maximum storm surge benefits are multiplied by the partial benefits curve percentage for each combination of renourishment interval and fill alternative. The steps to reach this calculation are found in BENEFIT SEG 1/2

[27] A table describes the layout and function of B-C Analysis at the end of this section.
[28] Excel Add-in @RISK must be running

sheets. The maximum possible storm protection benefits are given in cell D2. This is the weighted average of the annualized damages from the Retreat and Armoring Scenario Components derived in the VAR sheet rows 5 to 9.[29] The maximum storm protection benefit is used to derive the realized/actual storm damage benefits. The partial benefits curve is a range of beach widths with corresponding percentages of partial storm surge benefits that is displayed in VAR sheet rows 56 to 126. These partial benefits are weighted by the length of beach within seven ranges of widths shown in GENSESIS SEG 1/2 sheets, rows 53 to 99. The results are the weighted average percentage of storm damage benefits for all four fill alternatives across sixteen renourishment cycles shown in BENEFITS SEG 1, rows 31 to 37. This matrix of weighted average benefits is multiplied by the maximum potential storm surge benefits (cell D2) to derive the partial/realized storm surge benefits. Also included in this calculation are the recreation benefits, which are valued up to the partial storm surge benefits or the actual recreation benefits, whichever is less, in accordance with ER1105-2-100. The net present value and annualized benefits from this process are shown in BENEFIT SEG 1/2 from row 40 down.

Table 4.7-1 Selected Beach Widths and Corresponding Partial Benefits Curve Values (%)

feet	***90***	***100***	***110***	***120***	***……***	***170***	***180***	***190***	***200***	***210***
SEG 1	0%	0%	0%	6%	……	64%	72%	78%	83%	88%
SEG 2	0%	1%	6%	11%	……	33%	37%	41%	45%	49%

4.7.3 Beach Fill only & Hybrid Plan

A range of beach widths (50 to 200 additional feet) and renourishment cycles (2 to 16 years) are evaluated in *BC Analysis*. This is referred to as the ‘Beach Fill Only’ plan. In addition to the ‘Beach Fill Only’ plan, Coastal Engineers also evaluated placing semi-permanent fill inside the toe notches at the base of the bluff to augment each beach fill. This is referred to as the ‘Hybrid’ plan. These toe notch fills offers additional coastal storm surge damage reduction when minimal sand is present in the system to protect these coastal bluffs. To derive the protection factor, the toe notches for all parcels were set to zero feet in the *Armoring Scenario* spreadsheet. This approximates the initial conditions under the ‘Hybrid’ plan, which includes toe notch fills of similar density and durability as the surrounding sandstone. Next the excel add-in @RISK was used to run a simulation of erosion events (with *Erosion Rates* spreadsheet also open) on the parcels modeled in *Armoring Scenario.* The damages experienced by the unprotected parcels were compared to the damages experienced in a separate simulation in *Armoring Scenario* when the toe notches were not reset to zero feet (i.e. in their actual initial state). The percentage reduction is damages with the toe notches compared to unprotected properties with nonzero toe notches are the percent of additional coastal storm damage reduction benefits from the ‘Hybrid’ plan. These values are separated by segment and sea-level rise and stored in *BC Analysis, VAR* sheet for calculation in the *BENEFITS SEG 1/2* sheets.

[29] See B-C Analysis spreadsheet, VAR sheet at the top right. “Remaining Preventable Damages” is the result of weighting Armoring Damages and Retreat Damages then subtracting Sloughing Damages. See also “Weighting Armoring & Retreat Scenarios” earlier in this section.

Alternatives (net initial beach width change in feet)	Renourishment Cycles (years)	Sea-Level Rise Scenario
50	2 to 16	Low to High
100	2 to 16	Low to High
150	2 to 16	Low to High
200	2 to 16	Low to High

The additional costs of the toe notch fills in the 'Hybrid' plan are calculated in the *BC SUM SEG 1/2* sheets. These costs are added to each of the 'Beach Fill Only' alternatives calculated in the *COST SEG 1/2* sheets to determine the total costs for the 'Hybrid' plan as shown in *BC SUM SEG 1/2* sheets.

B-C Analysis retains the fill alternatives range from 50 feet to 200 feet of net increase to the initial shoreline width and the replenishment intervals range from two years to sixteen years. Each replenishment interval has a matrix that gives sand volume placements by each fill alternative and two sea-level rise scenarios. These matrices are found in Vol Lookup SEG 1/2 sheets. These volumes are used in the COST SEG 1/2 sheets to determine the variable cost to place a given amount of sand volume in the study area. The COST SEG 1/2 sheet combines the volume of sand placed with variable and fixed costs given in rows 2 to 6 to calculate the total costs in net present value of each renourishment interval and fill alternative across the study period. This information is laid out in matrices and the bottom of each matrix gives the net present value and annualized costs. A detailed description of how these costs are calculated is presented in the appendix under *With-Project Costs: Initial and Renourishment Fill*.

4.7.4 Presentation of Net Benefits

The benefits derived in BENEFIT SEG 1/2 and the costs derived in COST SEG 1/2 are summarized in the BC SUM SEG 1/2 sheet. The BC SUM SEG 1/2 sheet presents the benefit-cost ratio and the net benefits to arrive at the NED plan. It also calculates the additional cost to add toe notch fills to increase the storm surge protection of smaller beach width alternatives, which is labeled the "Hybrid Plan." The additional costs of the Hybrid Plan are shown in BC SUM 1 rows 93 to 116 and BC SUM 2 rows 137 to 168. The toe notch fill is placed during the initial year and continues to provide storm surge protection throughout the study period without maintenance costs. The additional benefits from the Hybrid Plan were derived by setting all toe notches to zero in the *Armoring and Retreat Scenario* to simulate the presence of toe notch fill. The partial benefits capture curve in VAR sheet rows 56 to 126 was adjusted by this percentage of added benefits, rows 57 to 61.

Table 4.7-2 B-C ANALYSIS BY SHEET WITH DESCRIPTION, INPUTS, AND OUTPUTS

Sheet[30]	Purpose/Description	Inputs	Outputs
VAR	Present key assumptions/inputs in one sheet, average annual without project damages (potential with-project benefits)	Armoring & Retreat Scenarios	n/a
REC BEN	Allow recreation benefits to be entered and evaluated with reduction to coastal storm damage benefits (BC SUM SEG 1/2 sheets)	Recreation Analysis With Project [separate spreadsheet] Recreation Analysis Without Project [separate spreadsheet]	n/a
SUM	Present Summary of Net Benefits and BC Ratios only	BS SUM SEG 1/2	n/a
GENESIS SEG 1	Segment 1 (Encinitas) Shoreline position across replenishment cycles for each project alternative; length of beach by width to determine full or partial storm surge protection benefits	Results from Genesis Model: changes to shoreline position, length of beach by width	n/a
BENEFIT SEG 1	Calculate partial benefits from storm surge provided by each combination of fill alternative and renourishment interval; determine annualized benefits for same	Benefits ○ weighted potential with-project benefits (from Armoring & Retreat Scenario) VAR ○ range of beach widths and corresponding partial benefits GENESIS SEG 1 ○ share of beach length of a given beach width	Partial benefits of storm surge protection by renourishment interval and fill alternative; annualized benefits
COST SEG 1	Calculate all associated sand replenishment costs; present annualized with-project costs.	VAR ○ fill cost per cubic yard, mo/demobilization, contingency, pre-construction engineering & design, SA, operation & maintenance, monitoring, environmental mitigation costs GENESIS SEG 1 ○ cubic yards of sand by fill alternative and renourishment interval	construction, monitoring, and operation & maintenance costs during the study period; average annualized costs
BC SUM SEG 1	Present annualized costs and benefits for each combination of alternative fill and replenishment cycle; calculate Net Benefits and BC Ratio; determine the NED Plan	COST SEG 1 ○ Annualized Costs BENEFIT SEG 1 ○ Annualized Benefits	Net Benefits, BC Ratio
Volume Lookup SEG 1	Provide volume of sand needed by fill alternative and replenishment cycle throughout study period	Results from Genesis Model: volumes of sand for each fill alternative and renourishment interval	n/a

[30] Sheets labeled GENESIS SEG 2, BENEFIT SEG 2, COST SEG 2, BC SUM SEG 2, and Volume Lookup SEG 2 refer to Segment 2 (Solana Beach) and are identical in layout and method of calculation to the sheets for Segment 1 shown in the table above.

1 **Table 4.7-3 1 PROBABILITY DISTRIBUTIONS USED IN MODELING**

Label	Distribution	Spreadsheet--Sheet	Description
Seawall Trigger	=RiskExtvalueAlt(0.05,4,0.95,36,RiskTruncate(-5,40))	Armoring Scenario --VAR	Minimum distance to bluff before armoring ("triggering event") derived from historical setback distances at time of seawall application
Seawall Trigger Delay	RiskUniform(1,2,3)		Delay in years between seeking seawall permit and receiving approval then constructing seawall; based on historical delay in within study area
Seawall Construction Costs	=RiskUniform(96000,150000,RiskStatic(180000))	Armoring/Retreat Scenario --VAR	Seawall Construction fixed costs including Permit, Design, Legal/Consulting derived from historical seawall construction in study area (most likely) with estimates of minimum and maximum
Seawall O&M Variable Costs	=RiskUniform(34,39)	Armoring/Retreat Scenario --VAR	Seawall O&M variable cost of repair (varies by linear feet of seawall) based on seawall engineer estimates
Seawall O&M Fixed Costs	=RiskUniform(2813,3214)	Armoring/Retreat Scenario --VAR	Seawall O&M fixed costs including permits, design, Legal/Consulting based on seawall engineer estimates
Erosion Rate Selection	=RiskIntUniform(1, 1000)	Armoring/Retreat Scenario & Sloughing Damage Analysis --VAR	Assigns uniform probability of choosing among 1000 simulated erosion rates for each year in the model. Note erosion rates are chosen from Erosion Rates spreadsheet

Label	Distribution	Spreadsheet--Sheet	Description
Demolition Costs	=RiskTriang(8.55,9.5,10.45,RiskStatic(9.5))	Retreat Scenario --VAR	Expert estimate of minimum, most likely, and maximum cost per square foot for demolition of structures
Percentage of Structure Content Damaged	=RiskTriang(10%,25%,50%,RiskStatic(25%))	Retreat Scenario --VAR	Percentage damage to structure contents when the structure fails from an episodic erosion event